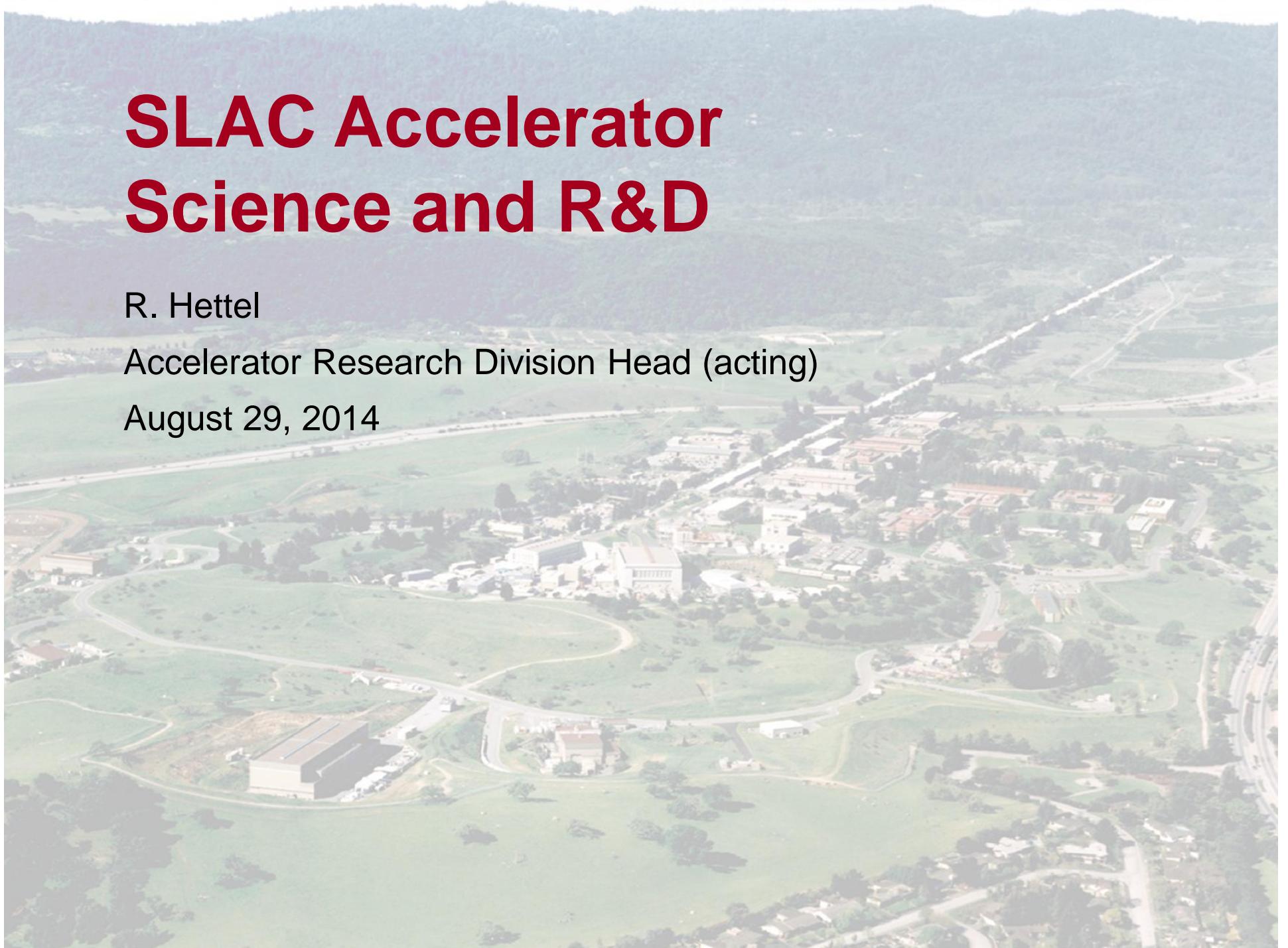


# **SLAC Accelerator Science and R&D**

R. Hettel

Accelerator Research Division Head (acting)

August 29, 2014



# SLAC Accelerator and Test Facilities

SLAC



# SLAC Accelerator Test Facilities for World Class R&D

SLAC

**Facet** (Facility for Advanced Accelerator Experimental Tests, 20 GeV):

- High gradient acceleration techniques (e.g. PWFA)
- High brightness beam and novel radiation techniques (e.g. for FELs, THz,  $\gamma$ -rays)
- High speed material science (e.g. fs magnetic switching)

**NLCTA** (NLC Test Accelerator, ~200 MeV X-band):

- X-band technology development (gun, linac, tcav, rf undulator, etc.)
- FEL seeding and beam manipulation R&D (BES)
- Direct laser acceleration
- Medical radiation tests

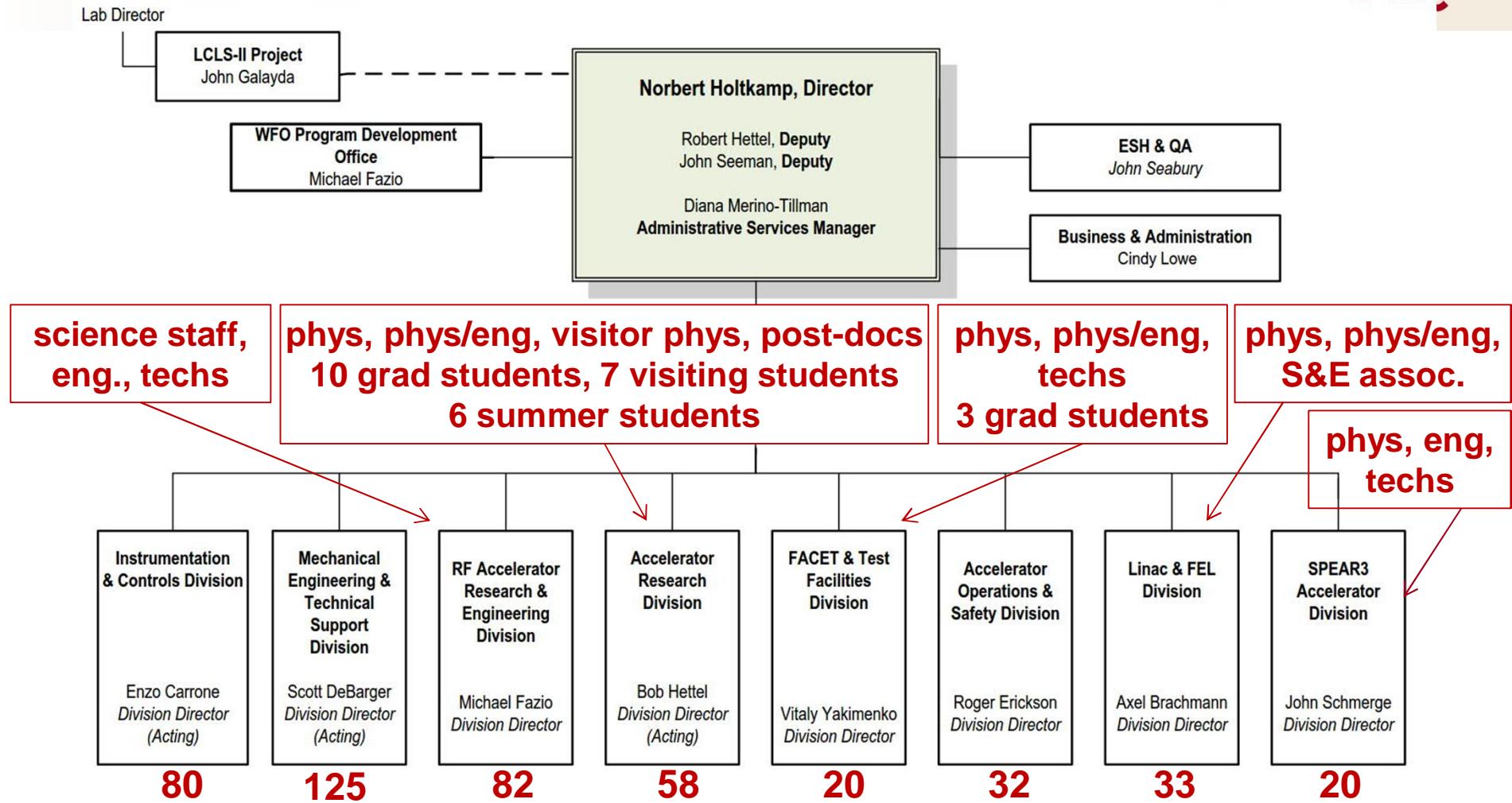
**ESTB** (End Station Test Beam, 2-16 GeV, single e-):

- Detector R&D, LC MDI, radiation tests

**ASTA** (Accelerator Structure Test Area, < 50 MeV, S- and X-band power):

- Gun and RF structure testing and processing (HEP and BES)
- UED (BES)

# SLAC Accelerator R&D – Staffing



- Many accelerator scientists and engineers have transitioned from HEP to BES R&D
- SLAC is a stronghold of accelerator physics competency

# SLAC Excellence in Accelerator Science and Technology



**APS Beam Physics Dissertation Prize:** T. Raubenheimer ('94), Z. Huang ('99), S. Prabhakar ('01), B. Podobedov ('02), D. Pritzkau ('03), D. Teytelman ('04), I. Blumenfeld ('11), D. Ratner ('12), S. Corde ('13)

**APS Fellows:** Y. Cai, A. Chao, P. Emma, J. Fox, J. Galayda, M. Hogan, A. Novokhatski, N. Phinney, T. Raubenheimer, R. Ruth, M. Ross, J. Seeman, G. Stupakov, S. Tantawi, J. Wang

**APS Wilson Prize:** J. Seeman ('04), J. Galayda ('13)

**DOE ECA:** Y. Ding ('10), F. Wang ('11), D. Xiang ('12), J. Wu ('13)

**DOE Award of Excellence:** J. Galayda ('11)

**DOE Appreciation Award:** Y. Ding, P. Emma, Z. Huang, J. Wu ('10)

**EPS Rolf Wideroe Prize:** P. Raimondi ('00), A. Chao ('08)

**EPS Frank Sacherer Prize:** A. Marinelli ('14)

**FEL Prize:** P. Emma ('09), J. Galayda ('12), D. Ratner (young scientist '12), D. Xiang (young scientist '13), Z. Huang ('14), E. Hemsing (young scientist '14)

**FPS Prix René Pellat, Prix de Thèse de l'École Polytechnique:** S. Corde ('13)

**IEEE Accelerator Award:** J. Seeman ('01), M. Hogan ('13) (V. Yakimenko '12)

**Innovation Award on Synchrotron Radiation:** P. Emma ('12)

**John Dawson Thesis Prize,** Laser and Plasma Accelerators Workshop: S. Corde ('13)

**USPAS Young Scientist Prize:** T. Raubenheimer ('01), S. Tantawi ('03), Z. Huang ('11)

# Overall Goals for SLAC Accelerator Research



## Maintain world-class accelerator science program

- World-class programs in beam physics theory, advanced computation, and accelerator design
- Operate SLAC's unique accelerators and test facilities
- Develop plasma- and laser-based advanced acceleration concepts

## Maintain a crucial, enabling role in technology development for future energy frontier colliders and other applications

Maintain NC technology support base for applications across OS

Develop novel RF source and accelerator technology for higher efficiency and compactness – from MHz to THz

Develop and industrialize RF sources for future accelerators

Establish customer base for RF technology developed by SLAC (including medical applications)

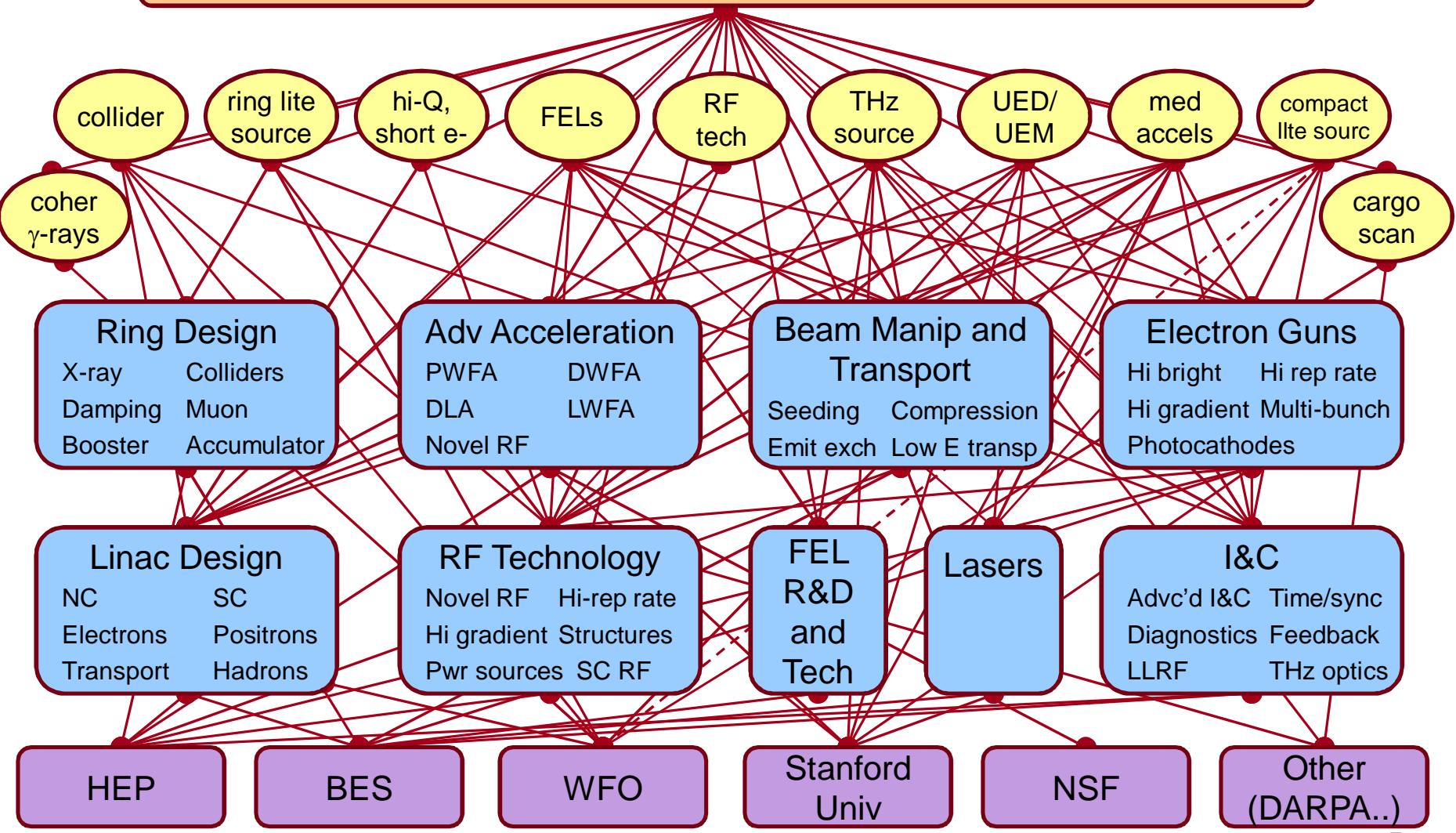
## Train next generation of accelerator scientists and engineers

# SLAC Accelerator R&D

## Core Competencies and Synergies

SLAC

Accelerator Facilities: LCLS, SPEAR3, FACET, NLCTA, ASTA, ESTB, KTL



# HEP Funding for SLAC Accelerator R&D



Fund	Program	FY13	FY14	FY15	FY16	FY17
GARD	Accel Phys & Comp	1293	1800	1550	1550	1550
	RF Technology	5371	5128	3250	3250	3250
	Novel Accel	5583	4450	4000	4000	4000
	LCC	427	325	1000	1000	1000
	Program Mgmt	254	700	700	700	700
	ECA - RF breakdown	621	500	500		
	Total GARD	13549	12903	11100	10500	10500
Directed Research	SciDAC	365	300	300	300	300
	LARP	1977	1615	1400	1400	1400
	MAP	485	475	125	125	
Test Facilities	FACET	9500	9500	9500	9500	9500
	NLCTA/ASTA			2000	2000	2000
	ESTB	300	390	500	500	500
<b>TOTAL</b>		26176	25183	24925	24325	24200

# Programmatic Research at SLAC - GARD



## Accelerator Physics, Design & Computation

- Beam and accelerator theory  
impedance, collective effects
- LC final focus and MDI studies
- LLRF and feedback
- Accelerator and RF computation
- Ring design (low emittance, colliders, SuperKEK-B, ...)
- FEL and light sources (BES funded)

### Future Goals:

- CSR theory and modeling
- High order nonlinear lattice theory, modeling
- Future collider studies
- Computing collaboration with LBNL and FNAL – CAMPA
- Diffraction limited light sources, FEL R&D (BES)

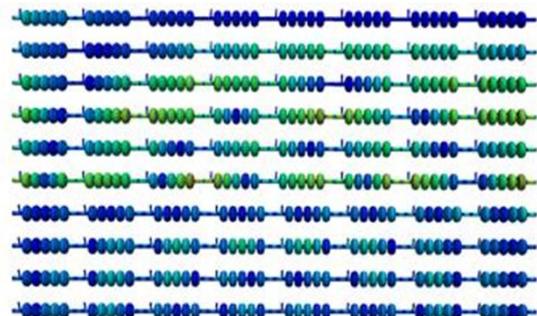
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 17, 020702 (2014)



Scaling law of coherent synchrotron radiation in a rectangular chamber

Yunhai Cai

SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA  
(Received 21 October 2013; published 12 February 2014)



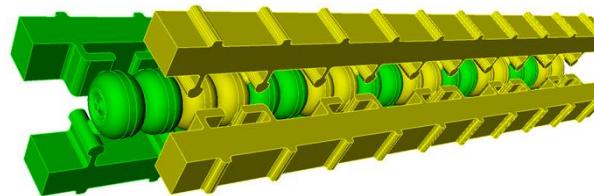
HOMs in PIP2 cryomodule using a hybrid linear solver: 3 min/mode, 300 cores, 1 TB of memory

# Programmatic Research at SLAC - GARD (cont.)

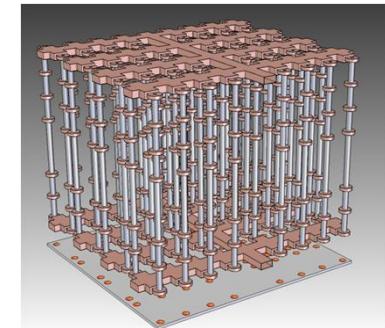
SLAC

## RF Technology

- Novel RF acceleration (high rep rate, novel sources, high efficiency klystrons, etc.)
- L-band modulators (ILC, MAP, PX)
- X-band RF gun
- NLCTA and ASTA ops
- ECA: RF breakdown



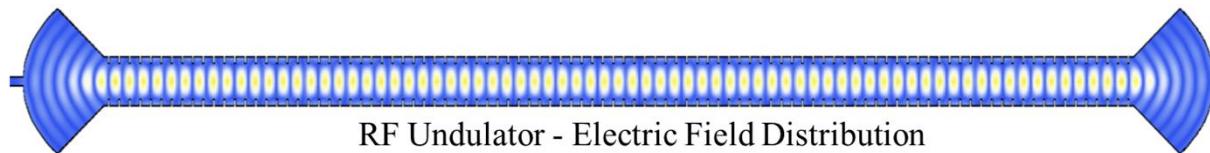
2-frequency acceleration



multi-beam klystron

## Future Goals:

- Initial designs for transformational RF sources and structures, extending to THz
- Explore scientific, medical, industrial and applications using new technology



RF Undulator - Electric Field Distribution



# Programmatic Research at SLAC - GARD (cont.)

SLAC

## Novel Acceleration

- Plasma Wakefield Acceleration (PWFA) at FACET
- Dielectric Laser Acceleration (DLA) at NLCTA

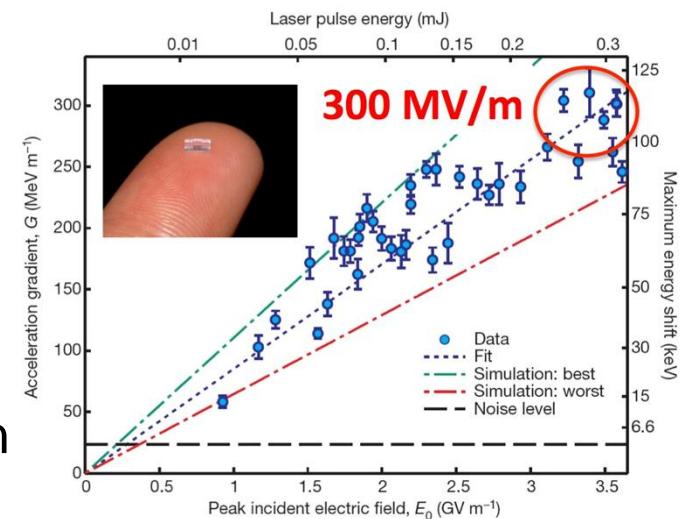
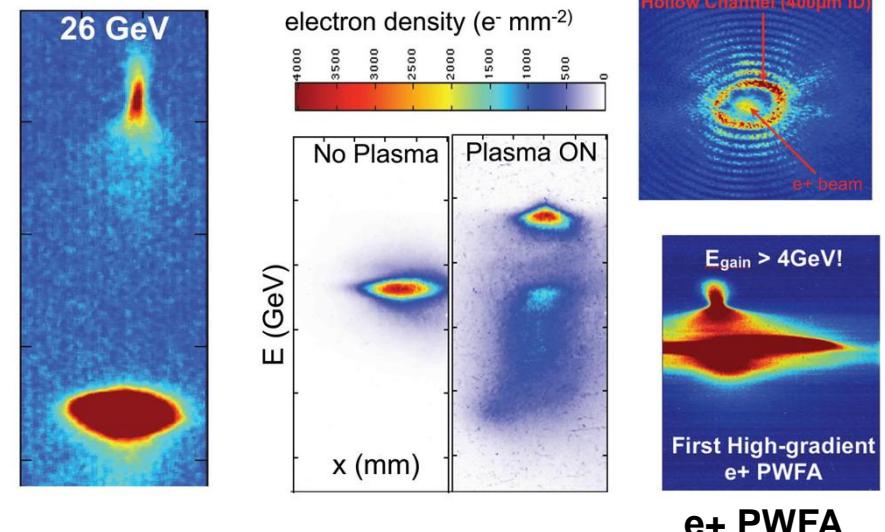
### Future Goals:

PWFA:

- witness bunch injector
- preserve emittance and efficiency
- positron acceleration
- study staging

DLA:

- higher gradient (GV/m) demonstrations
- attosecond bunching and net acceleration
- multiple stage acceleration



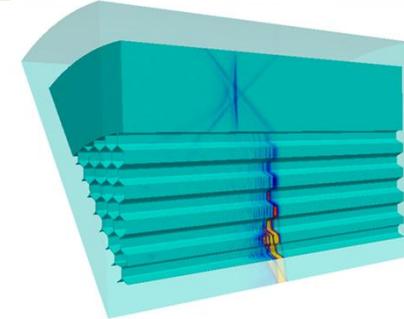
# Directed Research

SLAC

## SciDAC

- ACE3P development
- Collaboration with SciDAC Institute in computational science

**Future goals:** Develop multi-physics optimization for in modeling for accelerator design



Wakefield in a PBG fiber for DLA:  
5 hours using 14k cores

## LHC Accelerator Research (LARP)

- Wideband feedback system to suppress instabilities in SPS
- Design and simulations in support of HiLumi-LHC magnet and crab cavity projects
- Level 2 LARP management
- Toohig Fellowship Chair

**Future goals:** Demonstrate SPS feedback system by FY16 decision



SPS feedback kicker

# Directed Research

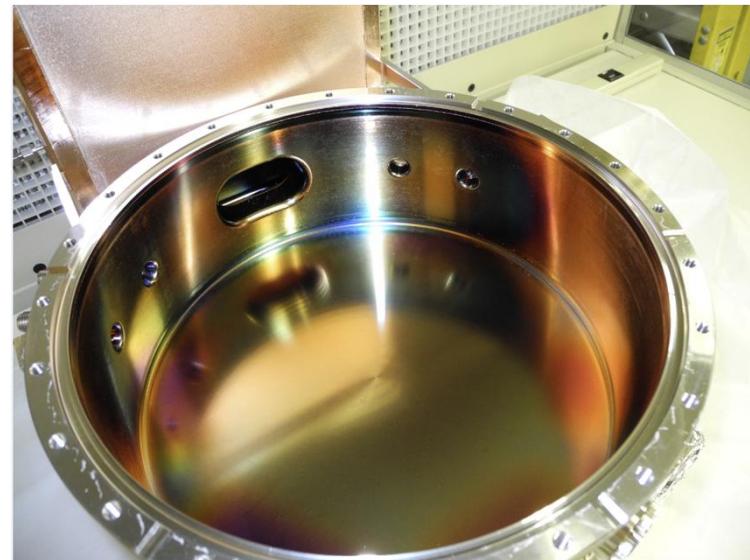
SLAC

## Muon Accelerators (MAP)

- Design and fabrication of RF cavity to operate in high magnetic field
- MAP scenarios study
- Machine detector interface and optics studies for muon collider

Program winding down

MAP RF cavity

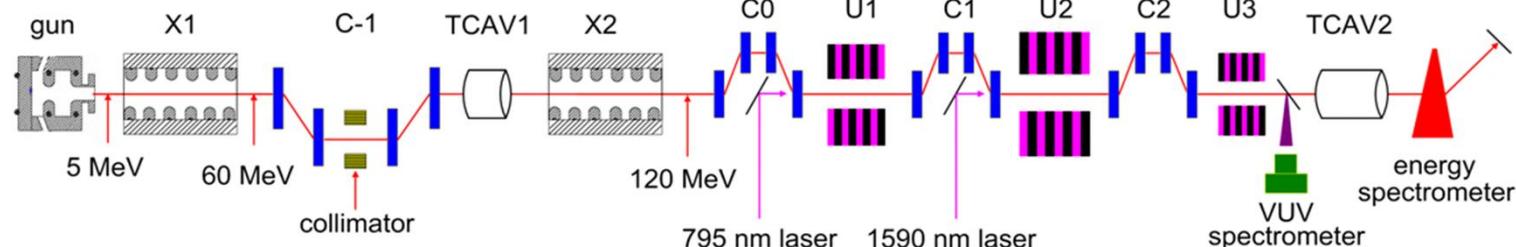


# FEL Accelerator R&D (BES)

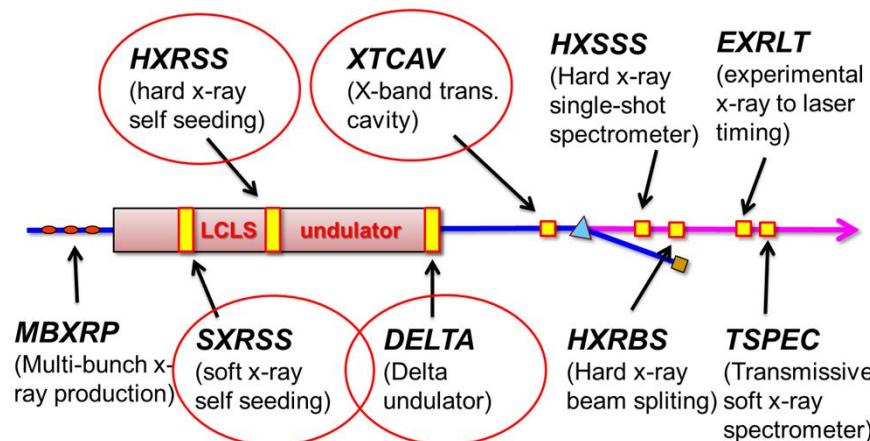


FEL research aimed at increasing photon pulse energy, reducing bandwidth, improving timing synchronization, increasing pulse repetition rate, producing 2-color photons, etc.

**NLCTA:** laser-electron seeding and manipulation (EEHG, ECHO, HGHG, QHG, OAM)



**LCLS:** FEL self-seeding, diagnostics, fs timing, enhanced photon power, etc.

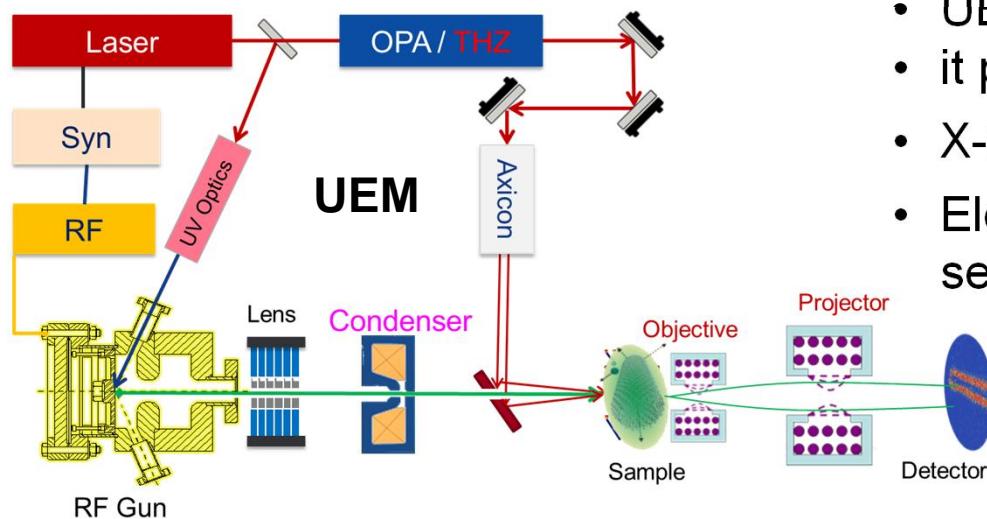


**fs timing,  
synchronization,  
measurement**

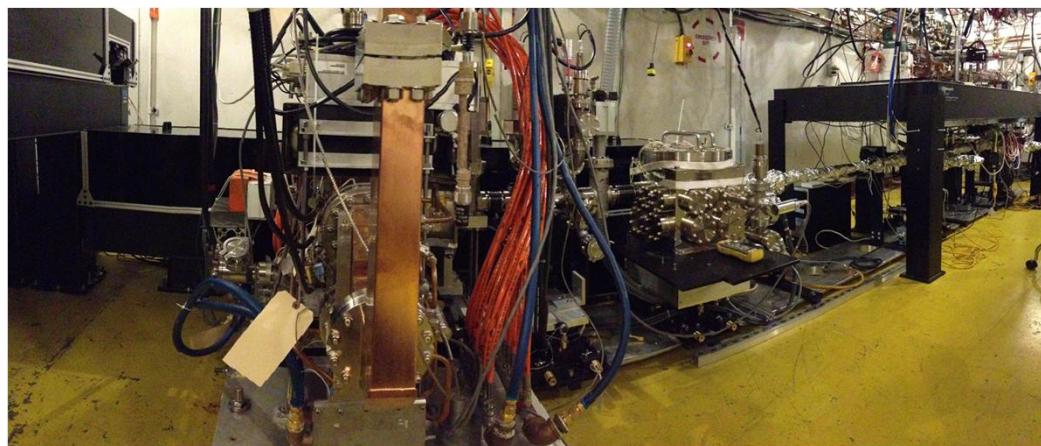
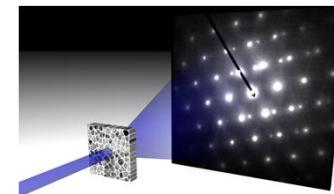
\* Coordinated program between AD (Huang) and LCLS (Hastings)

# Ultrafast Electron Diffraction and Microscopy (BES)

SLAC

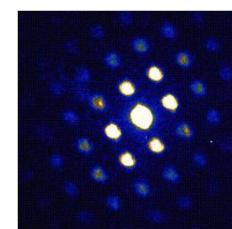


- UED probes lattice dynamics -
- it probes atom locations
- X-rays probes electron locations
- Electrons have high interaction cross-section – can probe dilute gases

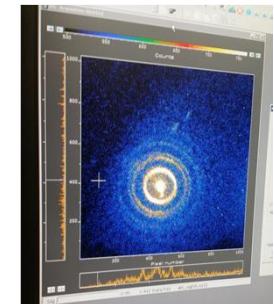


ASTA

- 1st diffraction patterns (hours after 1<sup>st</sup> operation)
- 4-month implementation in ASTA



Au



Bi

# Summary

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- SLAC accelerator science and research programs are diverse and productive.
- SLAC accelerator expertise and test facilities are critical resources for numerous HEP and stewardship programs
- SLAC accelerator expertise and test facilities are critical resources for educating the next generation of accelerator physicists and engineers.
- HEP support for these programs makes possible this cornerstone of the SLAC vision and mission.

# backup

# Budget Scenario B



Scenario B	Program - Research K\$		FY13	FY14	FY15	FY16	FY17
KA2501012	Accel Physics & Comp	TOTAL	\$ 1,293	\$ 1,650	\$ 1,650	\$ 1,650	\$ 1,650
	Beam Physics & Design		\$ 502	\$ 500	\$ 500	\$ 500	\$ 500
	Circular Collider Design		\$ 53	\$ -	\$ -	\$ -	\$ -
	Super KEK-B		\$ 102	\$ 150	\$ 150	\$ 150	\$ 150
	FF & MDI Studies		\$ 166	\$ 300	\$ 300	\$ 300	\$ 300
	LLRF & Feedback		\$ 254	\$ 200	\$ 200	\$ 200	\$ 200
	Accelerator Computation		\$ 216	\$ 500	\$ 500	\$ 500	\$ 500
	RF Technology	TOTAL	\$ 5,371	\$ 5,128	\$ 3,228	\$ 3,228	\$ 3,228
	High Gradient R&D		\$ -	\$ -	\$ -	\$ -	\$ -
	Novel RF Acceleration		\$ 1,748	\$ 1,478	\$ 2,128	\$ 2,228	\$ 2,228
	High Rep Rate NC Structures		\$ -	\$ 150	\$ -	\$ -	\$ -
	Novel RF Sources		\$ 508	\$ 500	\$ -	\$ -	\$ -
	Next Generation Efficient RF Sources		\$ -	\$ -	\$ 700	\$ 1,000	\$ 1,000
	ASTA Operation Upgrades		\$ 150	\$ -	\$ -	\$ -	\$ -
	NLCTA Operations		\$ 1,671	\$ 2,000	\$ -	\$ -	\$ -
	L-Band Marx Modulator Test Stand		\$ 303	\$ 100	\$ -	\$ -	\$ -
	X-Band RF Gun and Linac		\$ 991	\$ 900	\$ 400	\$ -	\$ -
	Novel Acceleration	TOTAL	\$ 5,583	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,000
	PWFA		\$ 2,200	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500
	FACET Upgrades		\$ 2,400	\$ -	\$ -	\$ -	\$ -
	DLA		\$ 983	\$ 1,500	\$ 1,500	\$ 1,500	\$ 1,500
	Linear Collider Collaboration	TOTAL	\$ 427	\$ 250	\$ 250	\$ 250	\$ 250
	Program Management	TOTAL	\$ 254	\$ 700	\$ 700	\$ 700	\$ 700
	ECA RF Breakdown Studies	TOTAL	\$ 621	\$ 500	\$ 500	\$ 500	\$ 500
KA2501012 Total - Genl Accel R&D			\$ 13,549	\$ 12,228	\$ 10,328	\$ 10,328	\$ 10,328
KA2501032 ESTB Operations		\$K	\$ 300	\$ -	\$ -	\$ -	\$ -
KA2501032 Total - Detector R&D			\$ 300	\$ -	\$ -	\$ -	\$ -
KA260102 HPRF Test Facility Stewardship	HPRF Testing Infrastructure for DOE & Industry		\$ -	\$ -	\$ -	\$ -	\$ -
KA260102 Total - Accel Stewardship			\$ -	\$ -	\$ -	\$ -	\$ -
Scenario B	Program - Directed/Competitive Research		FY13	FY14	FY15	FY16	FY17
KA2401021	SciDAC	\$K	\$ 365	\$ 365	\$ 365	\$ 365	\$ 365
KA2501021	LHC Accel Research	\$K	\$ 1,977	\$ 1,615	\$ 1,615	\$ 1,615	\$ 1,615
KA2501022	Muon Accelerators	\$K	\$ 485	\$ 475	\$ 475	\$ 475	\$ 475
KA250102A	ILC R&D	\$K	\$ -	\$ -	\$ -	\$ -	\$ -
SLAC Annual Bu	Total		\$ 2,827	\$ 2,455	\$ 2,455	\$ 2,455	\$ 2,455